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Evaluation of an Expedient Terrorist Vehicle Barrier

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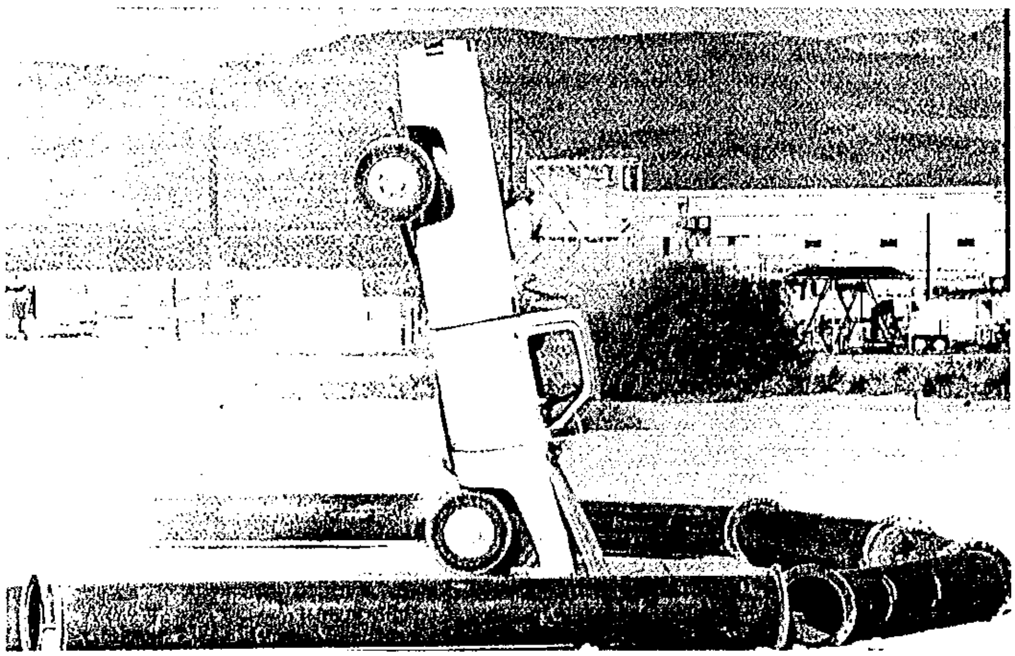
A Laboratory Directed Research and Development (LDRD) feasibility study



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Abstract

The threat of terrorist vehicle bombs has become evident in the past few years. The explosive power that can be generated by a 'home made" bomb carried by a standard van or moderate size truck can generate sufficient blast overpressures to cause major damage or catastrophic collapse to building structures. There are a number of means available to help prevent a successful terrorist attack on a facility. One measured consists of the gathering of intelligence that can be used to thwart an attack before it takes place. The design and retrofit of structures and structural systems which can resist blast loadings and protect occupants is another area which is currently receiving a great deal of attention by the security community. Another measure, which can be used to protect many existing facilities, is to restrict access to the facility. This option consists of keeping unauthorized vehicles as far as possible from the facility so that if a vehicle bomb does approach the facility, the distance at which the bomb is detonated will result in significant reduction in the overpressures by the time the blast wave reaches the protected structure. This paper describes a simple and efficient vehicle barrier concept that can be used to prevent unauthorized vehicle access. The feasibility study described herein consisted of a field experimental program to test the validity of the barrier concept, and demonstrated the ability of the simple barrier to effectively disable speeding vehicles.

1.0 Background

Recent events in the U.S. and abroad have demonstrated the potential for terrorist vehicle bombs to cause massive destruction to important facilities (Table 1). The effects of a vehi-

TABLE 1. Terrorist attacks against U.S. assets, 1983-1998.

Terrorist Event	Casualties
1983 Car Bomb, U.S. Embassy, Lebanon	63 killed
1984 Car Bomb, U.S. Embassy, Lebanon	11 killed
1986 Bomb, La Belle Disco, Germany	2 killed
1993 Car Bomb, World Trade Center, USA	6 killed, 1000 injured
1995 Car Bomb, U.S. Barracks, Saudi Arabia	7 injured
1995 Car Bomb, Federal Building, USA	168 killed
1996 Car Bomb, U.S. Barracks, Saudi Arabia	19 killed
1998 Car Bomb, U.S. Embassy, Tanzania	11 killed
1998 Car Bomb, U.S. Embassy, Kenya	213 killed, 5400 injured

cle bomb on a major structure can range from destruction of the cladding (i.e. the non-structural wall elements) of the structure, to progressive collapse of the structure. Progressive collapse occurs when a bomb blast causes sufficient local damage to the structure that the vertical gravity load path of the structure is destroyed and the gravity loads on the structure then lead to overall collapse of the structure (Figure 1). The structural system type can play a large role in determining whether or not progressive collapse occurs. The attack at the Murrah Building in Oklahoma City for example resulted in progressive collapse of a large portion of the building structure (Figure 2). The Murray Building was a reinforced concrete frame structure and the vehicle bomb caused extensive local destruction of the columns and the vertical gravity load path was destroyed locally. The existing frame system was incapable of redistributing the gravity load, and vertical collapse of the frame structure ensued. A similar attack occurred on the Khobar Tower building in Saudi Arabia (Figure 2). However, this structural system consisted of a shear wall lateral load system as opposed to the frame system of the Murrah Building. The result was that the powerful bomb caused extensive failure of external cladding, but the vertical load system was not severely damaged and the structure did not suffer progressive collapse.

The extensive damage caused by terrorist bombs is a result of the tremendously large overpressures which can be generated by a bomb created from readily obtainable commercial use materials. For example, the overpressures created at various distances for an explosive equivalent to 5000 lbs of TNT are shown in Figure 3. A terrorist can create this level of

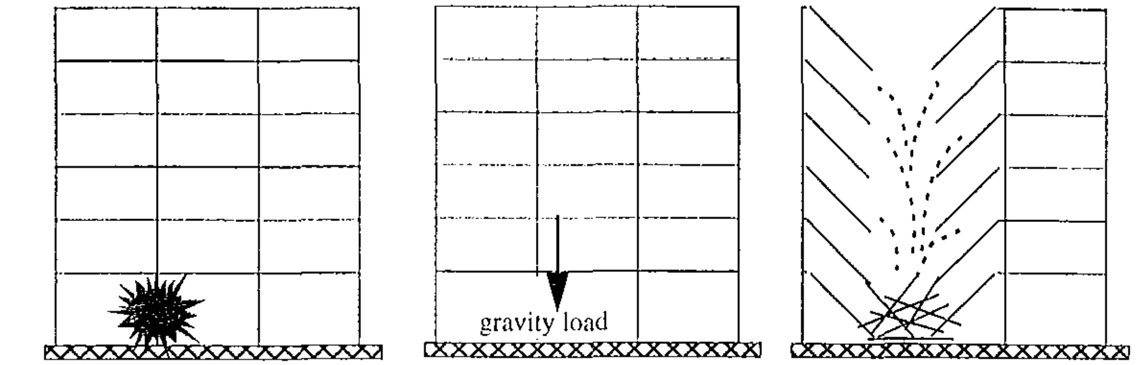


FIGURE 1. Progressive collapse of a building.

a)

b)

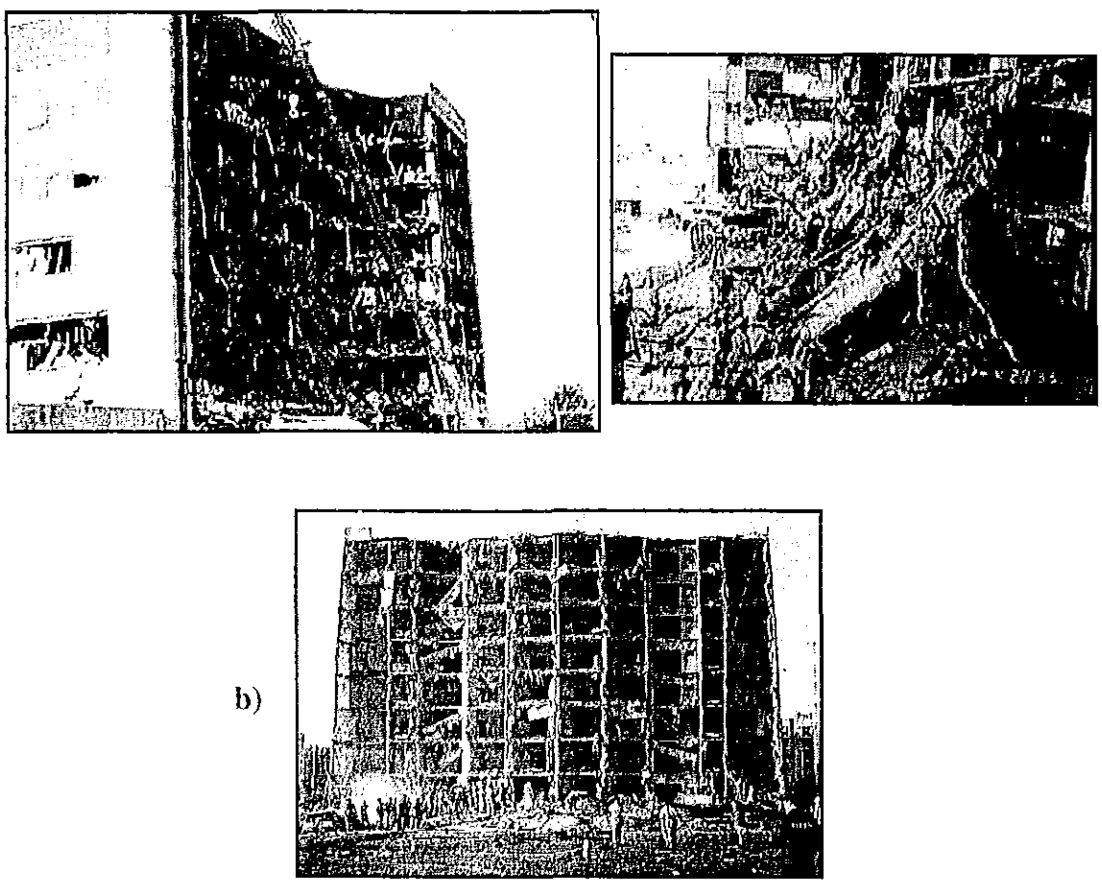


FIGURE 2. Terrorist attacks on U.S. infrastructure. a) Domestic terrorist attack on the Murrah Building, Oklahoma City resulting in progressive collapse; b) terrorist attack on the Khobar Tower Building, Saudi Arabia, resulting in extensive cladding destruction.

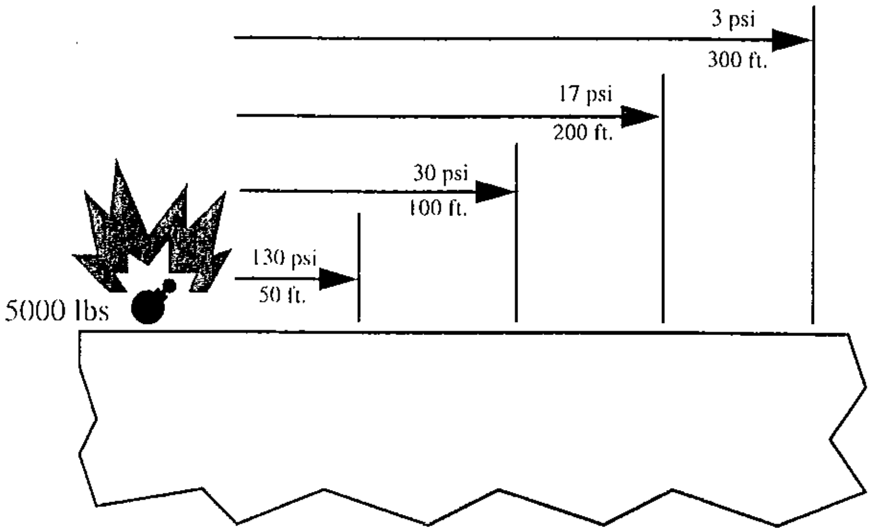


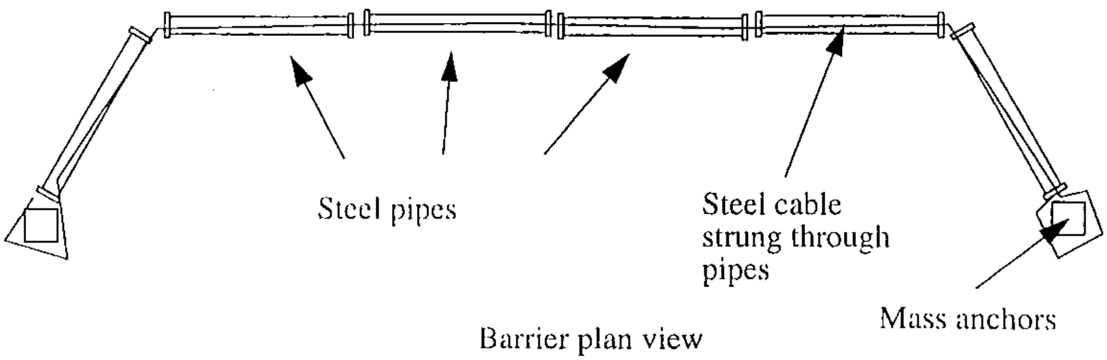
FIGURE 3. Blast overpressures as a function of distance for a bomb equivalent to 5000 pounds of TNT.

explosive with ammonium nitrate and fuel oil (ANFO) materials. Typical building structures may survive overpressures in the 2-3 psi range, but will likely be destroyed by overpressures on the order to 10-15 psi. Thus Figure 3 indicates that a significant stand-off distance must be maintained in order to protect a structure from a powerful vehicle bomb. This is obviously not feasible for many structures, such as important buildings located in downtown locations. However, for some important facilities, significant stand-off distances are achievable, and even for facilities where adequate stand-off cannot be achieved, maximizing the existing stand-off can assist in protecting the occupants.

The possibilities for stopping unauthorized vehicle access to critical facilities consist of human intervention, where armed guards are posted to prohibit passage, or physical barrier placement where a mechanical system is placed to prevent unauthorized vehicle passage. The human intervention alternative has proven a number of times to be an ineffectual method. Our notion of what represents rational behavior indicates that highly armed guards would provide a significant deterrent to a terrorist. However, a determined terrorist, willing to sacrifice their own life, is undeterred by bullets and bullets are ineffectual in stopping a speeding vehicle regardless of how many of the bullets strike the driver. In the attacks in Lebanon and Africa, armed guards were aware an attack was underway, but were unable to deter or prevent the attacks.

A number of possibilities exist for creating a physical barrier. However, there are often conflicts between limiting access for unauthorized vehicles and allowing access to authorized vehicles. The most widely used method of denying access is through the use of concrete rail barriers such as those found along highways (the most familiar being the "New Jersey" barrier denoting the state where it was originally designed and constructed). These massive concrete barriers can be very effective in stopping vehicles, however, they are massive and heavy, which requires the use of heavy equipment for placement. Once placed, the barrier can only be moved by bringing in heavy lifting equipment, and cannot be quickly changed to allow access status for authorized vehicles. In addition, these barriers may not be available in any location where a quick barrier is required, particularly at overseas sites where critical facilities or rapidly deployed forces might require short notice protection.

The purpose of the feasibility study described herein was to investigate the utility of a new alternate vehicle barrier concept. The alternative barrier, originally proposed by Wattenburg, consists of a steel cable strung through steel pipes and anchored on the ends as shown in Figure 4. The barrier can be constructed from readily available materials, which



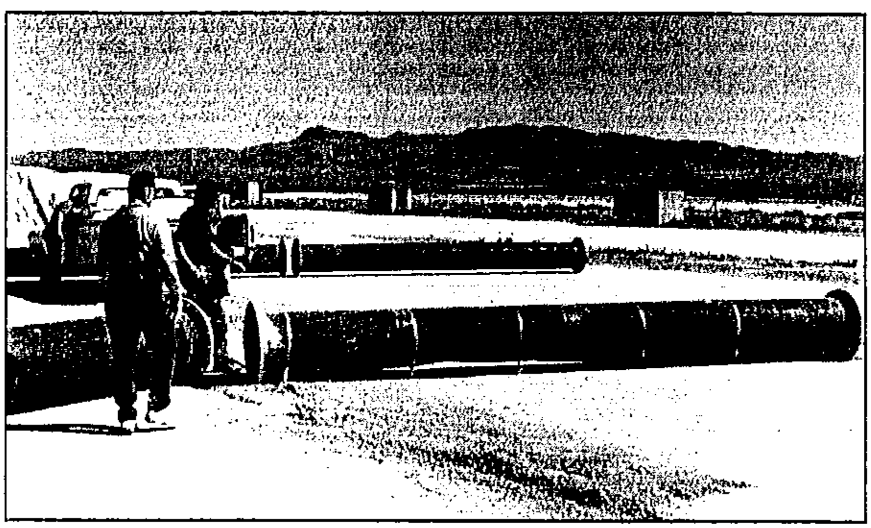


FIGURE 4. Flexible pipe barrier concept.

are obtainable essentially anywhere in the world, without the use of heavy equipment or specialized construction skills. The barrier is very light relative to concrete rail barriers and with the appropriate connection couplings, segments of the barrier could be moved by hand in a matter of minutes. The barrier is flexible provides some give when impacted by a speeding vehicle. The end masses provide the anchors for the cable system and react the inertial forces resulting from the vehicle impact. This barrier concept was tested with field experiments at the hazardous spill facility at the DOE's Nevada Test Site (NTS) north of Las Vegas.

2.0 Evaluating the pipe barrier concept

The pipe barrier concept was tested at the hazardous spill facility at NTS. The principal objective of this test was to ascertain the ability of the barrier to incapacitate a large speeding vehicle. Because of the remote location, and the availability of a flat wide open area, the NTS facility provided an ideal test bed for the barrier concept, and allowed for performance of a destructive test where the vehicles could be smashed into the barrier at high rates of speed.

The vehicle test area is shown in the photograph in Figure 5, this area provided an unrestricted vehicle run-up of approximately 600 ft. The site also had barrier construction

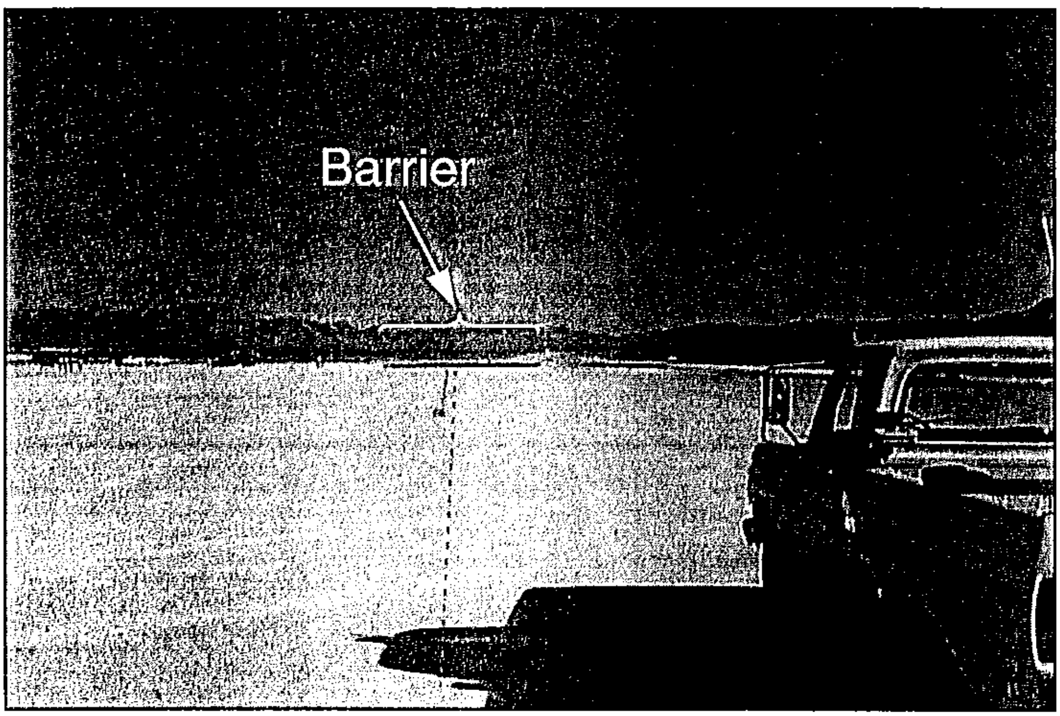
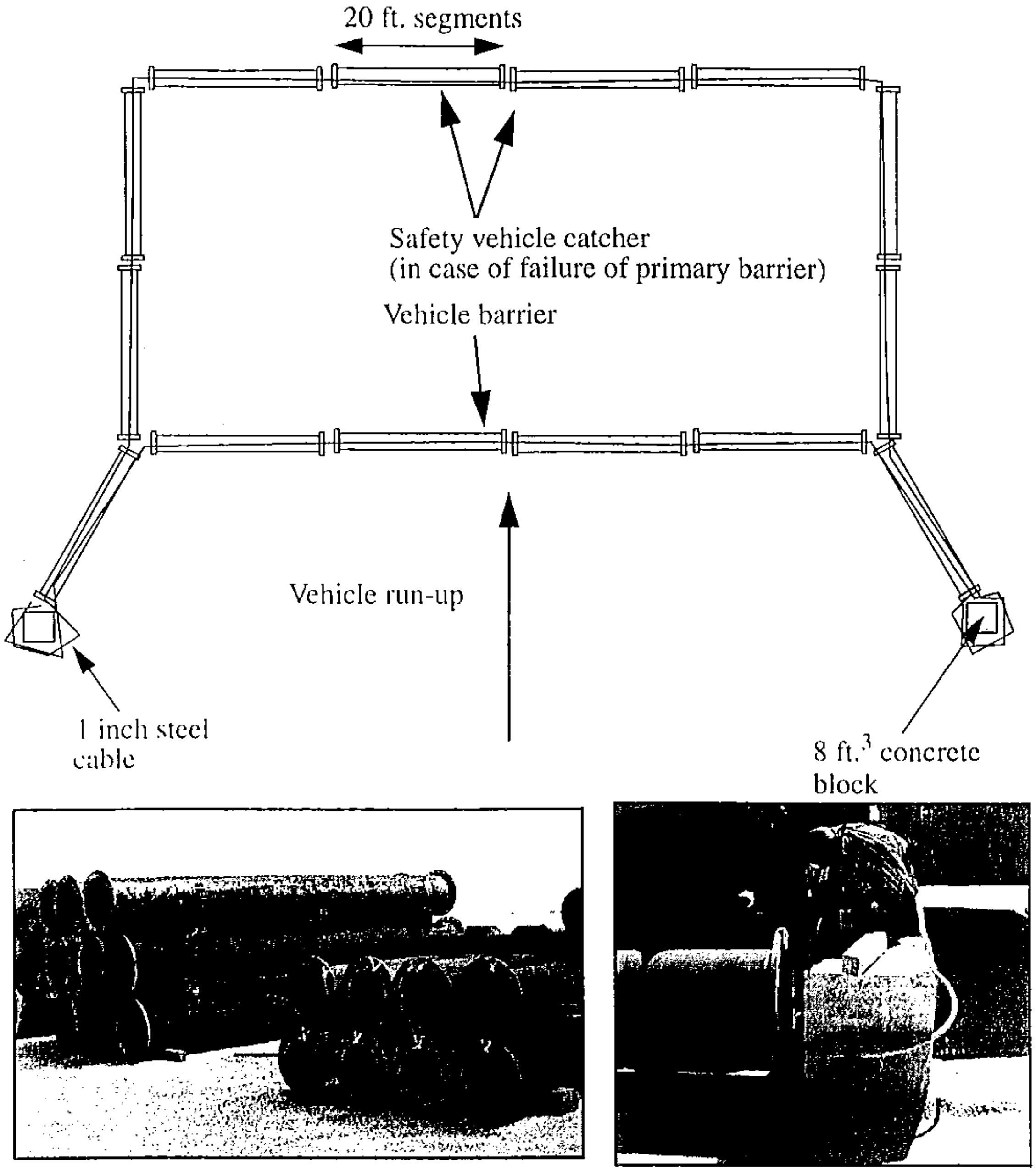


FIGURE 5. Vehicle run-up at the NTS spill facility.

materials available and two excess DOE vehicles were obtained from the NTS motorpool to serve as mock terrorist vehicles. The barrier was constructed with 24 inch steel pipe and one inch diameter steel cable. Existing concrete blocks were utilized as anchors at the ends of the barrier as shown in Figure 6. Since an objective of the experiment was to crash the vehicles into the barrier at high rates of speed, human drivers were out of the question and a remote control vehicle system was developed. The vehicle control system consisted of a radio commanded electronic control system mounted in the rear of the vehicle. The



Existing 24 inch diameter steel pipe stock

FIGURE 6. Test set-up for the pipe barrier experiments.

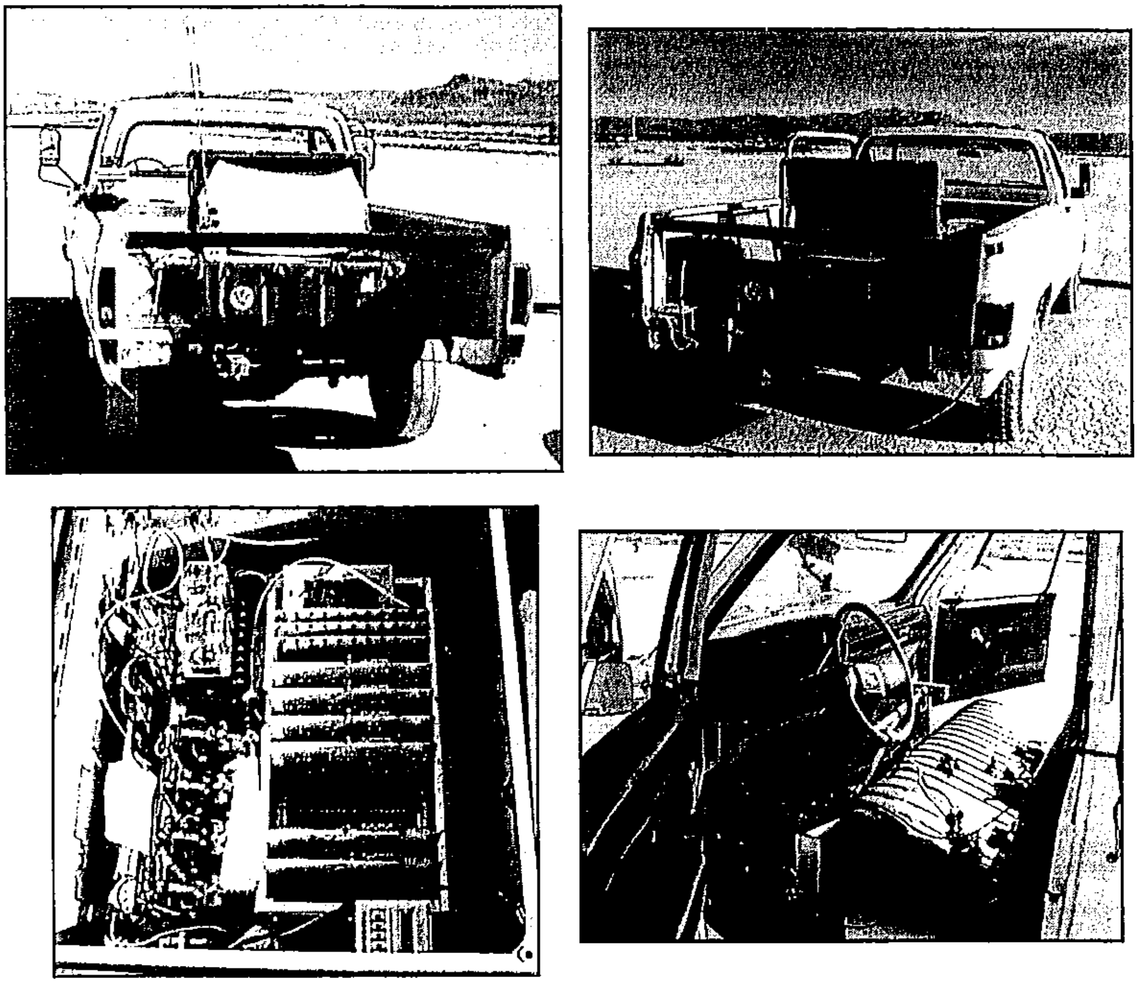
control system sent commands to a system of servos and linkages in the truck cabs which controlled steering, gas pedal, and brake as shown in Figure 7. Safety was of paramount concern and special redundant safety features were included on the vehicle. The safety aspects included an ignition system kill from the radio control box, a "time-out" timer on the vehicle which would kill the ignition system after a specified number of seconds, an accelerometer triggered ignition kill feature which would kill the ignition system after the accelerometers sensed large accelerations associated with impact, and finally the original vehicle fuel tanks were stripped from the vehicles and replace with a one gallon lawn mower tank to limit the fuel on board and minimize any fire hazard (Figure 7).

The field experiments consisted of running the vehicles into the barriers at speeds which were representative of what a terrorist vehicle bomb could practically achieve prior to impacting a barrier. Two experiments were conducted. In the first experiment a 3/4 ton truck loaded with approximately 500 pounds of sand bags to mock a bomb mass was crashed into the barrier at approximately 35 miles per hour. In this first experiment the vehicle hit the barrier with tremendous impact and was effectively launched into the air. Inspection of the vehicle indicated that the initial impact resulted in the motor shearing from the motor mounts and smashing up into the vehicle radiator. The initial impact also resulted in rupture of the vehicle drive line just behind the vehicle transmission. The destroyed vehicle came to rest right-side-up approximately 35 ft. beyond the original barrier location. Initially it was thought that leaving some slack in the cable would allow the barrier to translate somewhat and potentially allow the barrier to snag the vehicle in the barrier system. Careful slow-motion visual inspection of this first experiment provided some insight into the details of the interaction between the barrier and the vehicle. From the slow motion animation, it was clear that the vehicle moving at high speed impacts the barrier and is essentially launched in a vertical direction before the pipes in the barrier have enough time to respond and begin to move. Thus the slack which was purposefully left in the barrier cable during this first test was not utilized by the deforming barrier until the vehicle was long gone over the barrier. In light of this observation, the cables were brought to a taut configuration for the second vehicle experiment so that the impact would maximize the vehicle damage due to initial impact.

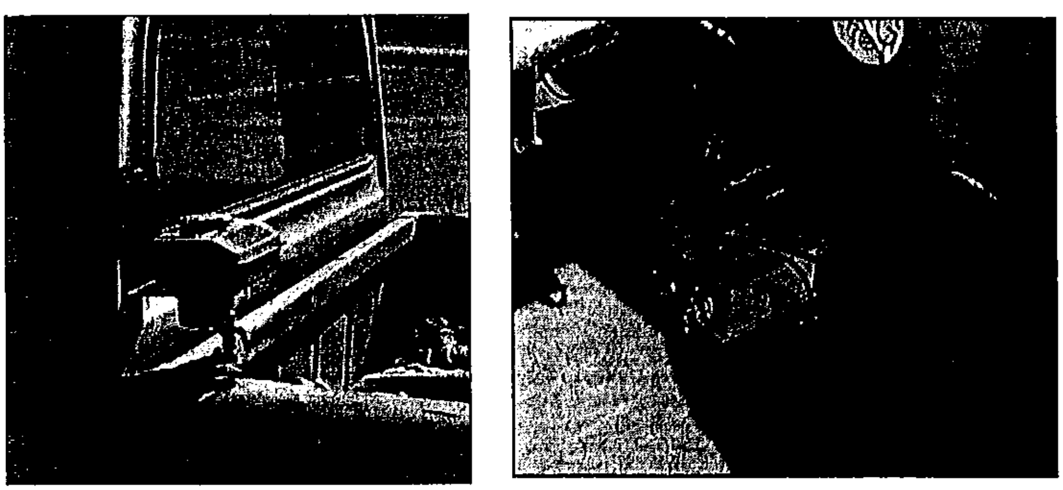
The second vehicle test utilized a one ton truck moving at approximately 42 miles per hour. Like the first experiment, this vehicle was loaded with approximately 500 pounds of sand to emulate some explosive weight in the bed of the truck. With the taught cable system, the barrier was stiffer and the when the truck attempted to bounce over the barrier, the taught cable system launched the rear of the vehicle vertically in addition to the front of the vehicle, the result being the vehicle totally flipped as it traversed the barrier as shown in Figure 9. The vehicle also exhibited the same power train damage characteristics as the first vehicle test, including a sheared off motor and broken drive shaft. A sequence of video segments illustrating the vehicle-barrier impact are shown in Figure 10.

3.0 Conclusions

The expedient pipe barrier can be utilized to disable heavy duty, speeding terrorist vehicles. The experiments indicated that a vehicle impacting this barrier at speed will be subjected to a violent impact and tremendous forces and the drive train of the system will likely be disabled through decoupling of the motor from the motor mounts and decoupling of the drive line system. Everyone has experience the large dynamic forces which result when a relatively small highway speed bump is hit at slightly too high a speed (say 8-10 m.p.h.), extrapolate that to a much larger "bump" and higher speed and a physical intuition of the level of forces at play in the barrier impact can be developed.



a)



b)

FIGURE 7. Test vehicle hardware. a) Electronic controller and control servos and linkages; b) safety features including reduced gas reservoir and accelerometer for ignition kill.

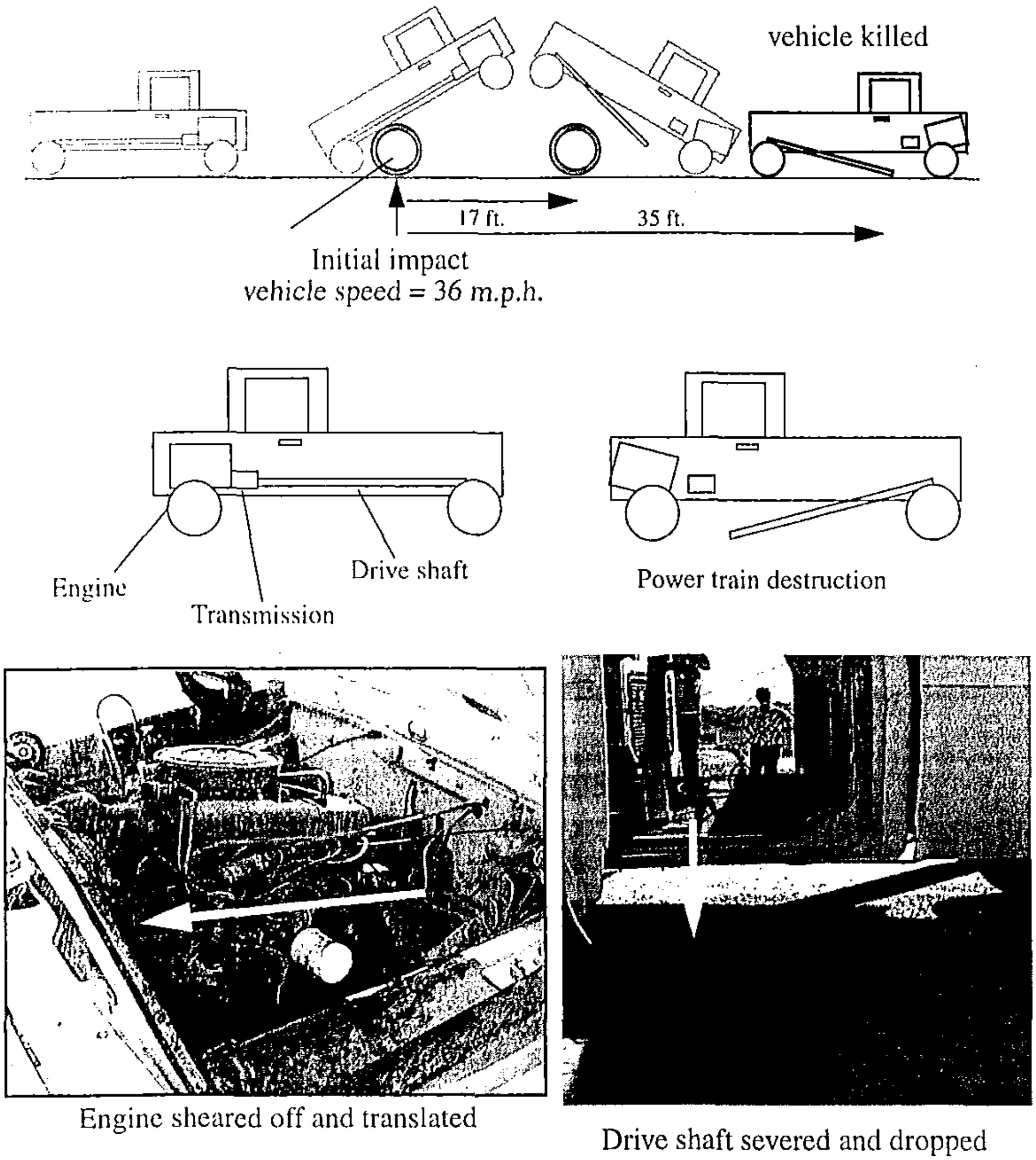


FIGURE 8. Vehicle destruction from the first vehicle experiment.

The pipes used in the field experiment were 24 inches in diameter and this diameter was employed because of the availability from the existing pipe stockpile at NTS. With this diameter pipe, the bumpers of the trucks impacted near the top of the pipe. As a result, the vehicles tended to be launched vertically upon impact. So although the vehicles were completely disabled, they did physically end up over the barrier. It is likely that a larger diameter pipe, 36 inch pipe for example, would have less tendency for sending the vehicle in the vertical direction and would result in a more violent collision, with more energy trans-

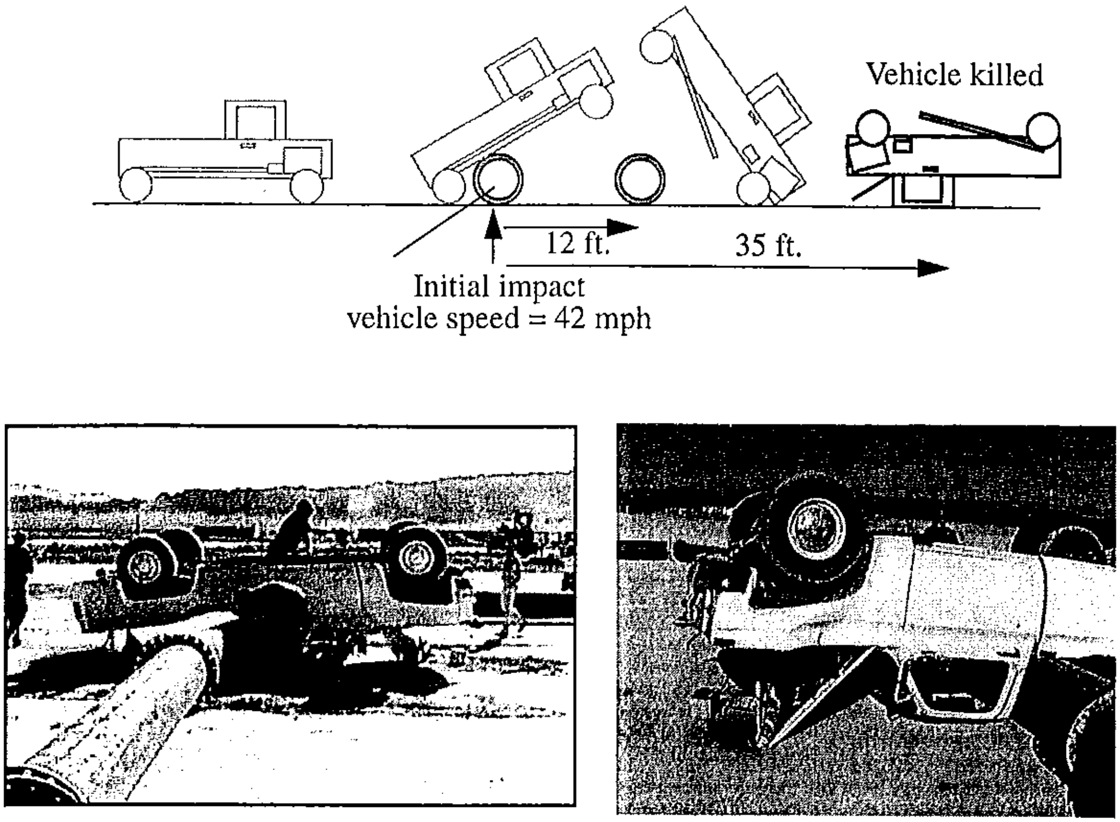


FIGURE 9. Vehicle destruction during the second field test.

ferred to the vehicle system, and would tend to snare the vehicle in the barrier rather than allow the vehicle to vault vertically and move over the barrier. In order to optimize the barrier design, it would be desirable to test larger diameter pipe barriers in the future to validate any fundamental improvements which might result in the barrier performance.

This expedient barrier should not necessarily be viewed as a replacement for standard concrete barriers for all applications. However, where a need arises for a quick and easily constructed barrier, which must be constructed from readily available materials on hand, this barrier design can be very useful to deny unauthorized vehicle access. The barrier also has potential for applications in which there is a mixed need for authorized vehicle access and unauthorized vehicle denial, where the barrier must be moved and replaced at frequent intervals.

Acknowledgements

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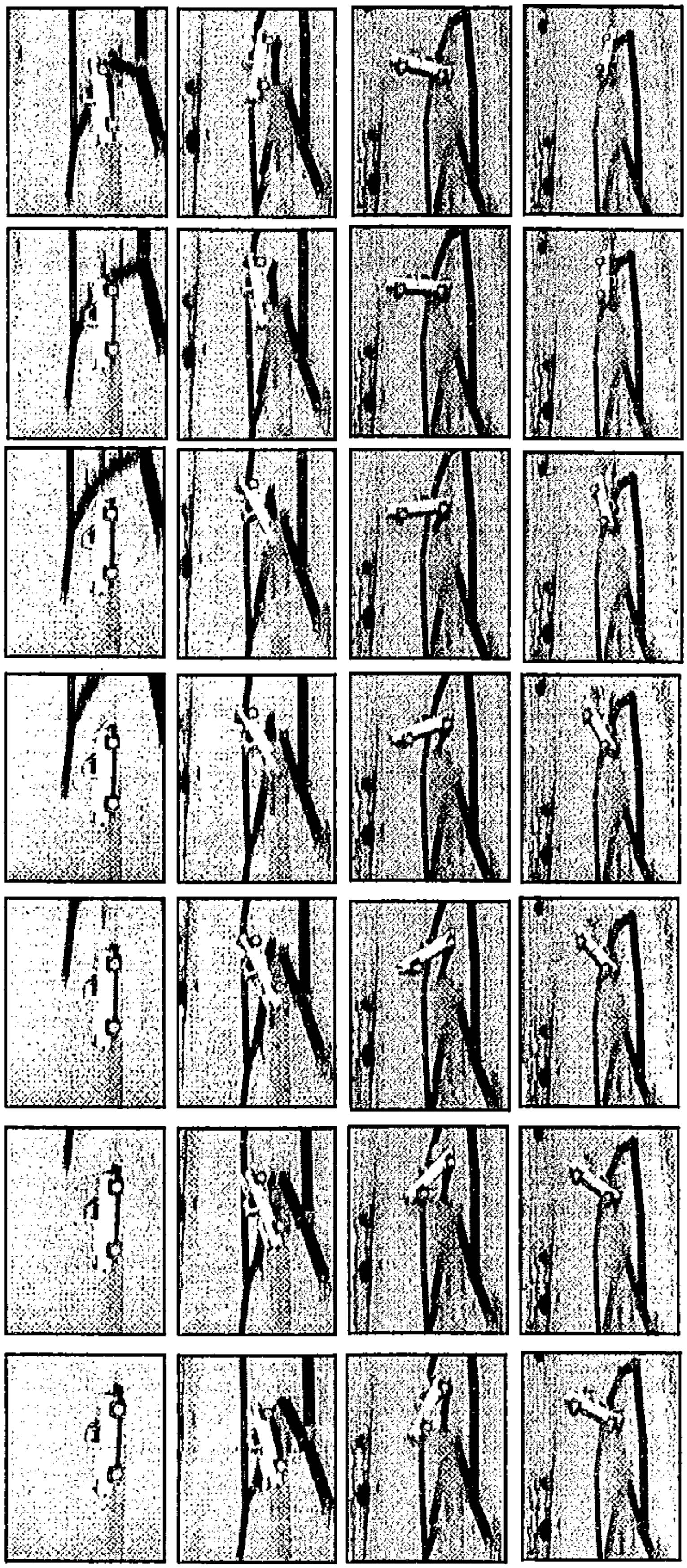

FIGURE 10. Sequence of frames showing vehicle - barrier impact during the second vehicle test.